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# SIMULATION MODELLING OF PERMANENT MAGNET SYNCHRONOUS MACHINE USING ARTIFICIAL NEURAL NETWORK WITH PWM TECHNIQUE

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***ABSTRACT***

***Today many electrical drives use the mechanical gear and pulley system to control the speed of prime mover for the generator which causes greater number of losses and wear and tear losses. So to eliminate these losses we can use the ANN techniques. In this paper work controlling of permanent magnet synchronous generator is done by controlling the firing angle of the voltage source inverter using an artificial neural network with PWM technique. The pulses of PWM generator is controlled by using the ANN system. The low speed drives are used for wind power generators. The best generator for Wind power generator is Permanent Magnet Synchronous generator as it works in low speed, compact and reduced weight. This scheme shown is using double ANN controller with PID error Analyser. Today wind power generators are utilised greatly in renewable energy conversion technique. The proposed circuit can be utilised for wind power generation units.***

***KEYWORDS: Artificial Neural Network (ANN), VOLTAGE Source Inverter, PID (Proportional-Integral Derivative), Permanent Magnet Synchronous Generator (PMSG), Speed Controller, MATLAB Simulation Modeling, Pulse Width Modulation (PWM)***

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Original Article

## INTRODUCTION

Permanent Magnet generator has no rotor winding which results in lesser copper losses and therefore feature a higher efficiency than any induction generators. The PM synchronous generators are widely used in many electric vehicles system and wind power generating units due to their varied advantages such as compactness, higher efficiency, wide constant power region and high power density. For low-speed applications, below 300 rpm, Permanent Magnet generators further eliminate the need for a gearbox. To adapt the speed and torque of the generator, a gearbox is generally coupled to a standard induction generator. It is advantageous to remove this mechanical element because it is very costly, decreases the drives efficiency, and needs higher maintenance. Lower-speed (or higher-speed) drives without any gearbox are termed as *direct drive*, since the generators are compact and directly coupled with the load. As PID (Proportional-Integral Derivative) speed controllers are sensitive to variation in variables so we used it to eliminate the errors caused in the system and to train the ANN controller. To attain the desired speed operation we use firing angle circuit by using PWM generator [10], [12]. Many Researchers are using parameter-insensitive genetic algorithm and fuzzy logic controllers (FLC‟s) to control the speed of PMSG. However, both the genetic and Fuzzy system are complex and non sensitive to change in Parameters and require extreme care in implementation. The Least mean square algorithm incorporated along with fuzzy inference, optimizes the weights used for combining the rules, which in

turn makes the controller more efficient. The modified robust Extended Kalman Filter (EKF) rejects the outliers in real-time, thereby eliminating the need for manual intervention in tuning the parameters of the EKF [3], [6].

## WIND POWER GENERATION

In recent years there is a rapid increase in the production of wind power generation in India the major states in India for wind power generation are Gujarat, Tamilnadu, Andhra Pradesh, Rajasthan etc. The major components of wind power generation system are Turbine, generator, convertor, battery for storage, Gear system and controller. The main constrained in wind power generation is the cost and less power generation. The cost of the production of system is decreased by bulk production and subsidies given by the Govt. The power generation is increased by increasing the efficiency of the generator and at constant wind speed. Constant speed is not possible so we generally use the gear system for improvement in speed but it increases the losses. To decrease the losses we use the ANN controlling technique to remove the gear system.

## INVERTER

The artificial neural network ANN, often called the neural network is based on human brain working technique. An ANN is particularly used for solving many different problems of image recognition, probability solving etc. It has been applied with success in control of Active power filter and is very promising in the field. The learning capacities of the ANNs allow an online adaptation to every changing parameter of the electrical network, e.g., nonlinear and time-varying loads. Most of these control constraints are quite still very challenging with classic control methods [2], [15]. Artificial neural network based permanent magnet synchronous generator drives have been used. ANN utilizes many controlling techniques some are the conventional static training algorithm known as error back propagation (BP) severely restricts its use for applications requiring real-time adaptation, normal multilayer feed forward artificial neural network (FANN) which deals with static problems inherently[1], [4]. This paper proposes an ANN (Artificial Neural Networks) based PWM controller for the permanent magnet synchronous generator in which it precisely and accurately follows variation in speed and also provide variable speed operation. The ANN technique is used to control the speed of the PMSG. The system is simplified to a double artificial neuron (DAN) to minimize complexity and computational burden requirements [17], [13].

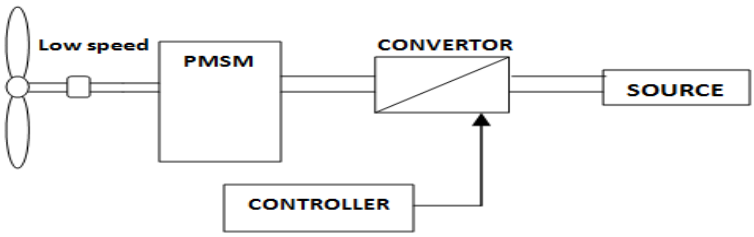


**Figure 1: Direct Drive**

Various modulation strategies likewise SPWM (Sinusoidal PWM), Non-sinusoidal PWM, SVPWM (Space-Vector PWM), Sigma delta modulation and SHE (Selective Harmonic Elimination), minimum ripple current PWM,have been suggested for multilevel inverters that decrease the undesired harmonics and control the output voltage of voltage source inverter [8-9]. SHE (selected harmonic analyser) it is utilised to eliminate the lower order harmonics completely and to control the fundamental voltage. The disadvantage of SHE Harmonic technique is that elimination of lower order harmonics increases the level of higher order harmonics. The sinusoidal pulse width modulation (SPWM) is modulation technique used where power switching inverter is utilised [6], [10].The space vector modulation technique is the most

advanced and computational intensive PWM method. The SVM method considers the interaction with phases and optimizes the harmonic contents. Sigma delta modulation is used in high frequency converter system to generate variable frequency and variable frequency voltage wave. The application of ANN is generally growing in power electronics and electrical drives system. In the control of dc–ac inverters, ANNs are being used in the voltage control of inverters for ac generator drives. A feed forward artificial neural network basically implements nonlinear input-output mapping. For any arbitrary chosen objective function, the optimal switching pattern depends on the desired modulation technique.

## PERMANENT MAGNET SYNCHRONOUS GENERATOR

The use of permanent magnets (PMs) in construction of electrical machines brings the benefits of higher torque and/or output power per volume than when using electromagnetic excitation, simplification of construction and maintenance, no electrical energy is absorbed by the field excitation system and thus there are no excitation losses which means substantial increase In the efficiency, better dynamic performance than motors with electromagnetic excitation (higher magnetic flux density in the air gap), reduction of prices for some types of machines. The development of a high quality permanent magnet material into a commercial production has encouraged several manufacturers to launch various permanent magnet synchronous generators into the market for various applications. The use of PM brushless motors has become a more attractive option than induction motors as Rare earth PMs can not only improve the motor's steady-state performance but also the power density (output power-to-mass ratio), dynamic performance, and quality. The prices of rare earth magnets are also dropping, which is making these motors more popular. The improvements made in the field of semiconductor drives have meant that the control of brushless motors has become easier and cost effective, with the possibility of operating the motor over a large range of speeds and still maintaining a good efficiency.

Voltage equation is

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + p \begin{bmatrix} L_a & L_{ba} & L_{ca} \\ L_{ba} & L_b & L_{cb} \\ L_{ca} & L_{cb} & L_c \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \quad (1)$$

Voltage equation in dq reference frame

$$v_d = Ri_d + p\lambda_d - \omega_r\lambda_q \quad (2)$$

$$\lambda_q = L_q\, i_q \quad (3)$$

$$v_q = Ri_q + p\lambda_q - \omega_r\lambda_d \quad (4)$$

$$\lambda_d = L_d\, i_d \quad (5)$$

Torque equation is

$$T_E = \frac{3P\left(\lambda_{af}\, i_q + (L_d - L_q)\, i_d\, i_q\right)}{4} \quad (6)$$

The equation (1) describes the basic voltage equation of the permanent magnet synchronous generator. The voltage equations can also be written in the simplified way as mentioned by the equation (2) and (4). These equations are useful in the calculation of efficiency of the generator. And the equations (3) and (5) define the expression of the flux linkages. General characteristics of PMSG is high efficiency, Compact in size, Smooth torque, Low acoustic noise, Fast dynamic response [11].

## ARTIFICIAL NEURAL NETWORK IMPLEMENTATION

The implementation of the feed forward neural network is done to generate the switching angles based on the simple harmonic analyzer strategy in order to cancel the 5th, 7th and 11th harmonic and to control the fundamental voltage of the AC output voltage given by the considered inverter.

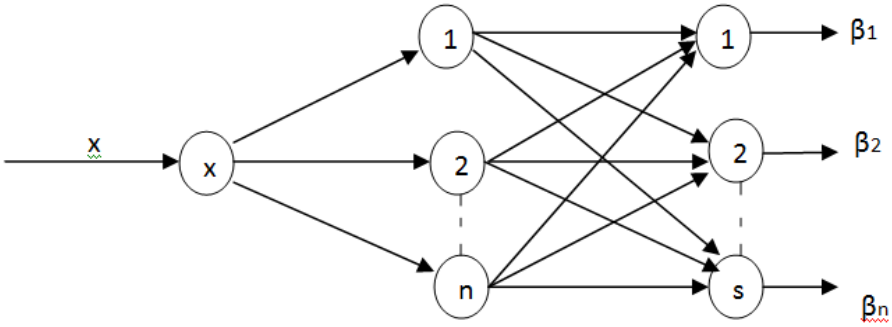


**Figure 2: ANN Structure**

The ANN is used for generation of the optimal switching angles has a double input neuron fed from the modulated index, one hidden layer and *s* outputs where each output represents a switching angle as shown in fig- 2. The sets of angle those are required to eliminate 5th, 7th, 11th and 13th harmonics, etc given by equation (5). The ANN is trained from the back-propagation algorithm of the Mean Square Error (MSE) between the output and the desired value of the system. The training set for the network has been produced off-line by solving these nonlinear equations using Newton-Raphson method. To implement this algorithm, MATLAB programming is used which in turn makes the process fast and easy. When a set of input values are presented to the ANN, step by step calculations are preceded in the forward direction to drive the output pattern. The mean square error MSE) generated from the set of input patterns is minimized by gradient descent method altering the weights one at a time starting from the output layer [3-15]. The training algorithm (BPA) is summarized in Figure 3.

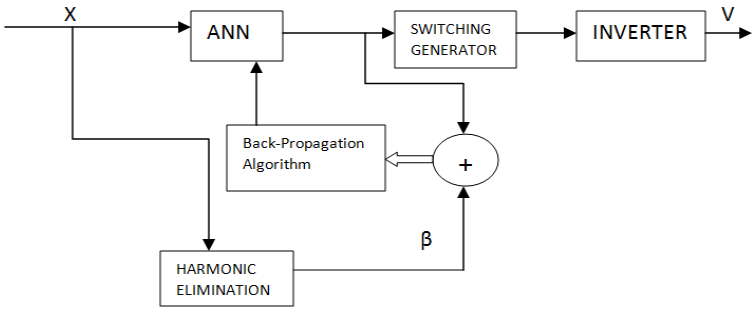


**Figure 3: ANN Back-Propagation Algorithm**

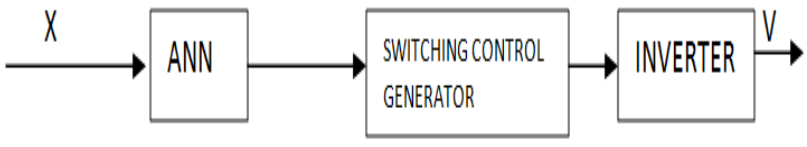


**Figure 4: ANN Control of Inverter**

The ANN control algorithm is implemented using X-file program. After the termination of the training phase, the obtained ANN can be used to generate the control sequence of the inverter

## CIRCUIT TO BE IMPLEMENTED

As shown Figure -5 the turbine provides the mechanical power to the permanent magnet synchronous generator which is connected to the transmission line. Controlling of the PMSG is done by using the rectifier which is powered by the supply source or by the line itself. The rectifier is connected to inverter; the inverter is controlled using the firing angle which is connected to the stator of the PMSG. The ANN controller is connected to the PWM generator which controls the firing angle of the Inverter. The three phase AC supply is given to the diode rectifier which converts alternating current to direct current and reduces harmonic ripples. The controller output is given to the driving circuit from that the output signals are given to the gate terminals of the switching devices.

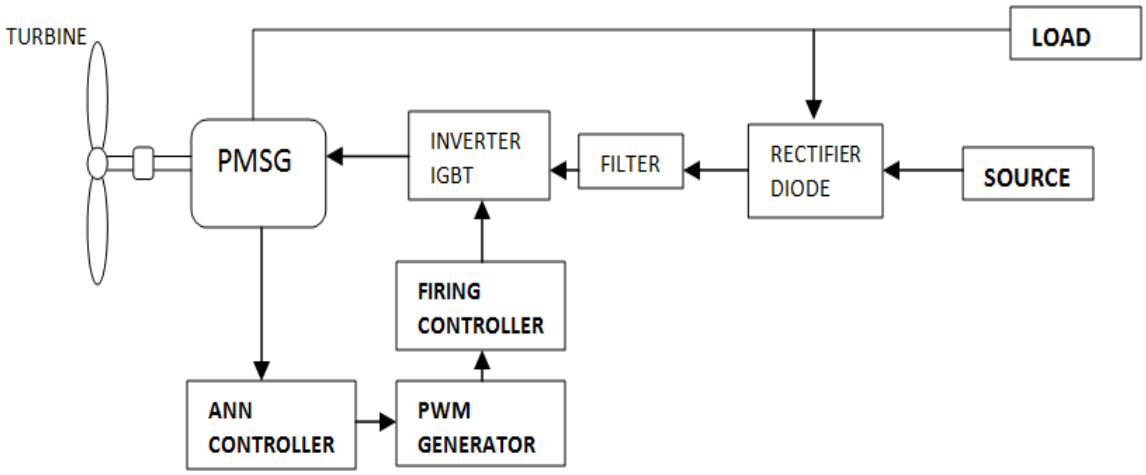


**Figure 5: Circuit Diagram of Proposed ANN Based Control of PMSG Drive**

An inverter is a power electronics device that converts direct current to alternating current; the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching firing angle, and control units. The output of the inverter is given to the permanent magnet synchronous generator. A rectifier is a device that converts' alternating current, which periodically reverses direction, to direct current, which flows in only in one direction. This process is known as rectification. Then utilizing capacitor and inductor, rectifier is connected to the voltage source inverter and this ensures the maximum power factor in the inverter side. The voltage source inverter consists of six switches which is IGBT in this system. A power IGBT is a type of insulated gate bipolar transistor (IGBT) designed to work on significant power levels. Compared to the other power semiconducting devices, for example MOSFET (metal oxide semiconductor field effect transistor), GTO gate turn of thyristor. The main advantages are high commutation speed and good efficiency at low voltages. The power IGBT is the most widely used low-voltage (that is, less than 450 V) switch. It can be found mostly in power supplies, DC to AC converters, and voltage generator controllers.

## SIMULATION AND RESULTS

The ANN based controller is utilized for controlling the speed of permanent magnet synchronous generator utilizing the PWM (pulse width modulation) technique. This system is simulated in the below diagram using Matlab software.

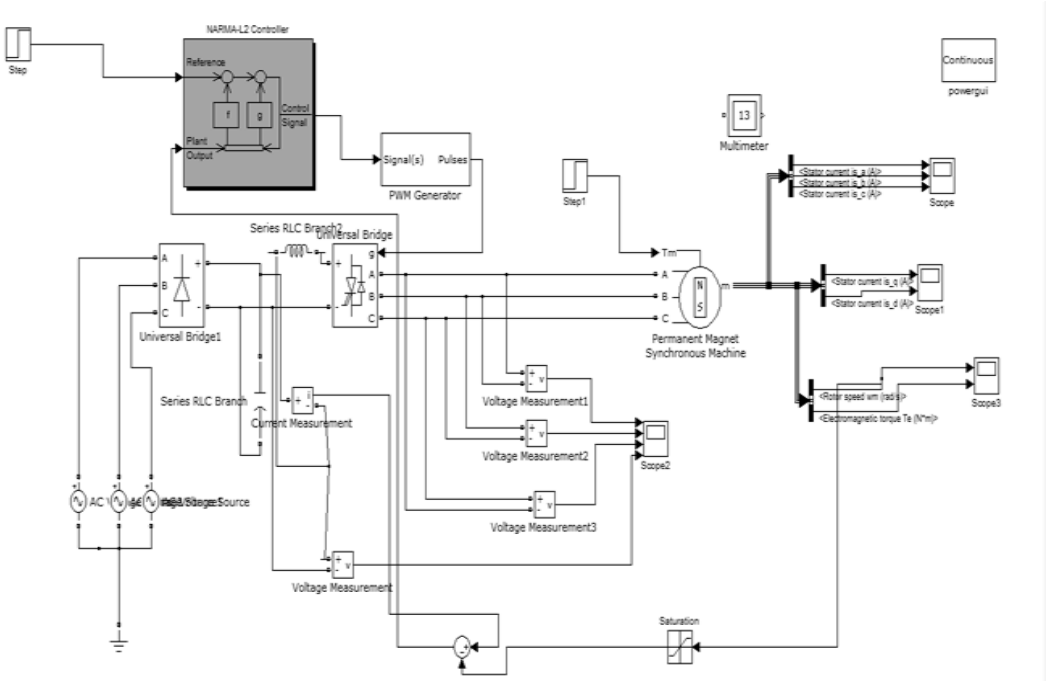


**Figure 6: Simulation of Main Circuit**

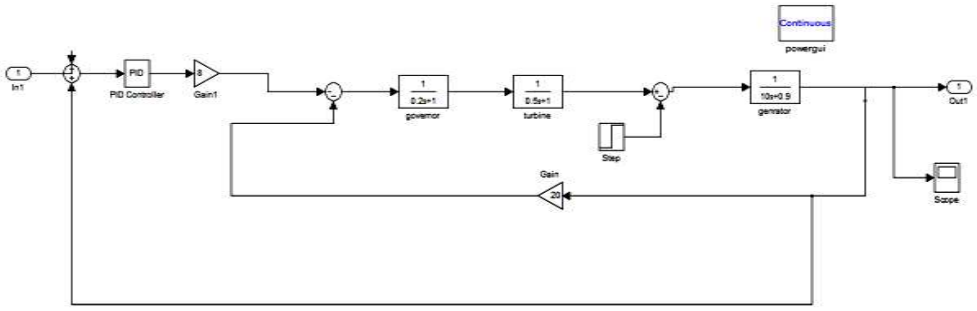


**Figure 7: Simulation of Auxiliary Circuit**

Figure 7 shows the auxiliary PID circuit which is used for elimination the error in the circuit. It is having a negative feedback control system. In Figure 6 Matlab diagram we use the 440V supply which act as a main generator source and is given to the three phase inverter and before that it is rectified by using the bridge rectifier. The ANN circuit is supplied with speed and current feedback system which provide signal to the PWM generation system. The power factor is maximized by the circuit consists of inductor, capacitor, and one switch i.e., IGBT. Fig-8- shows the waveforms of the source voltage and DC bus voltage which is given to the generator. The voltage rating is about 440V and the current rating is about 3A. The voltage of fewer ripples and with improved power factor is given to the generator. And the generator operates with certain speed. Shows the waveform of stator current of the generator for each phase. Figure 10 shows the less ripple content in the each phase of the current i.e., $i_a$, $i_b$, $i_c$. These output current from the generator are about ±3 A about 400V and the current rating is about 3A. The voltage and current of fewer ripples and with improved power factor is given to the generator. And the generator operates with certain speed.

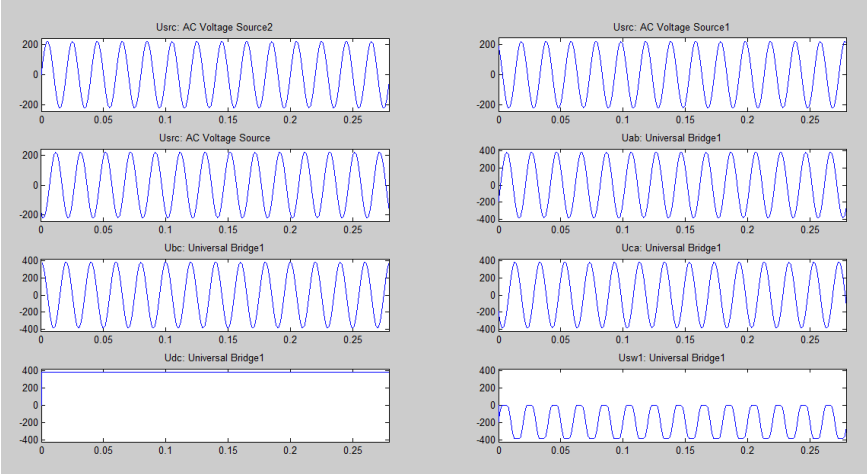


**Figure 8: Wave Form for Supply Voltage, dc Bus Voltage**

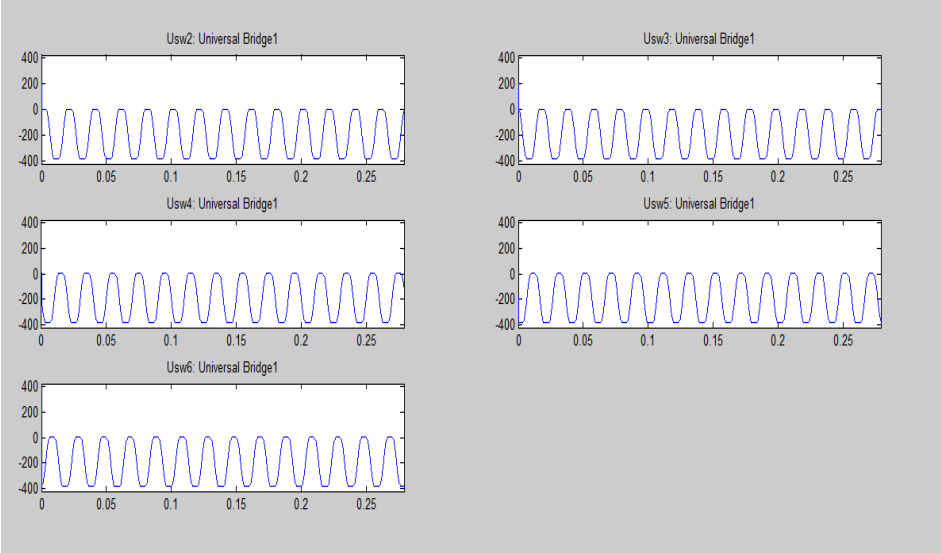


**Figure 9: Convertor Bridge Wave Form**

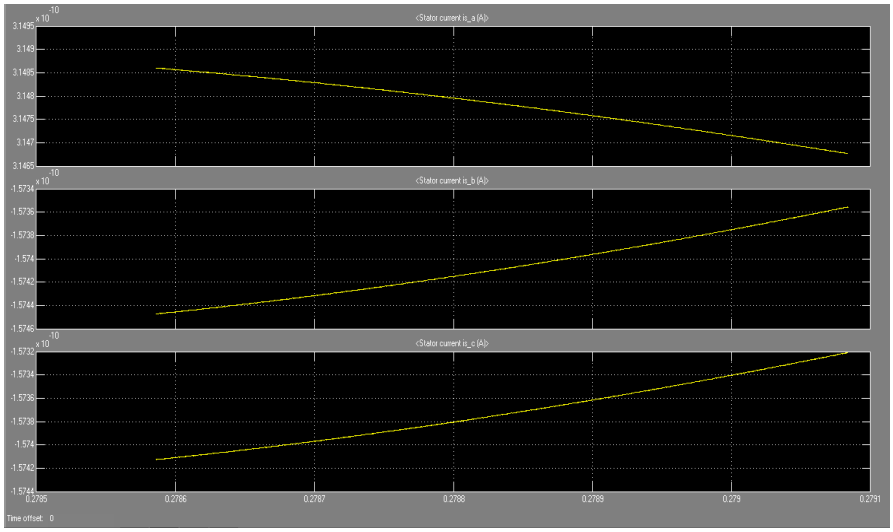

**Figure 10: Stator Currents Wave Form**

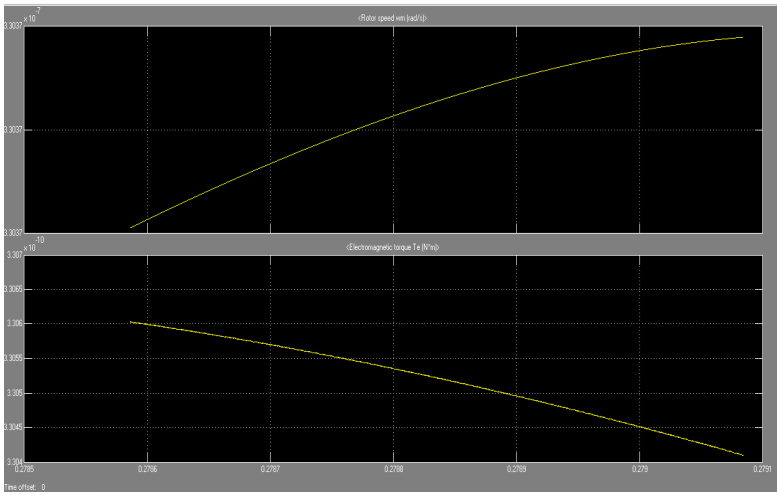

**Figure 11: Speed and Electromagnetic -Torque Wave Form**

## CONCLUSIONS

Figure no-8 shows the AC voltage and DC bus voltage waveform input in the circuit. Figure no-9 shows the convertor voltage and current waveform that are provided by the Multimeter. Figure no-10 shows the current waveform of stator side generator. Figure no-11 shows the speed and electromagnetic torque waveform. The values can be more improved by using other techniques like genetic algorithm, Fuzzy logic controller method etc. but ANN is far better technique with PWM control method for generator based system. The error that occurs in the circuit can be treated by using the PID controller system which is the basic training for ANN system.

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## APPENDIXES

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